Subliminal ATC Utilizing 4D Trajectory Negotiation

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Overview

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- ERASMUS Program
- Subliminal Control Concept
- 4D Trajectory Management
- Subliminal Control System Architecture
- Technology Readiness
- Potential Benefits and Conclusion

ERASMUS : En Route Air traffic Soft Management Ultimate System

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- **European Commission-funded project**
  - 30 months, start May 2006
  - Targets 2011-2017 timeframe
  - Partners: EUR, HON, ETH, SDER, LIU, SICTA
- **Objective**
  - **Maintain safety, efficiency in midst of projected traffic increase.**
    - Air-traffic in Europe, around the world projected to double every 10 to 14 years;
    - Higher rates of growth expected in the U.S., Asia and trans-oceanic airspace.
    - ICAO forecasts a growth in world air travel of 5% per annum until 2020.
    - Increased ATCo workload contributed to 33% increase in U.S. controller errors from 1996-2000.
- **Approach**
  - **Increase ground-based automation to alleviate pressures on ATCo**
  - **Exploit advanced technologies and concepts**
    - area navigation,
    - air/ground communication
    - high precision airborne system capabilities
    - 4 D trajectory management

What is subliminal control?

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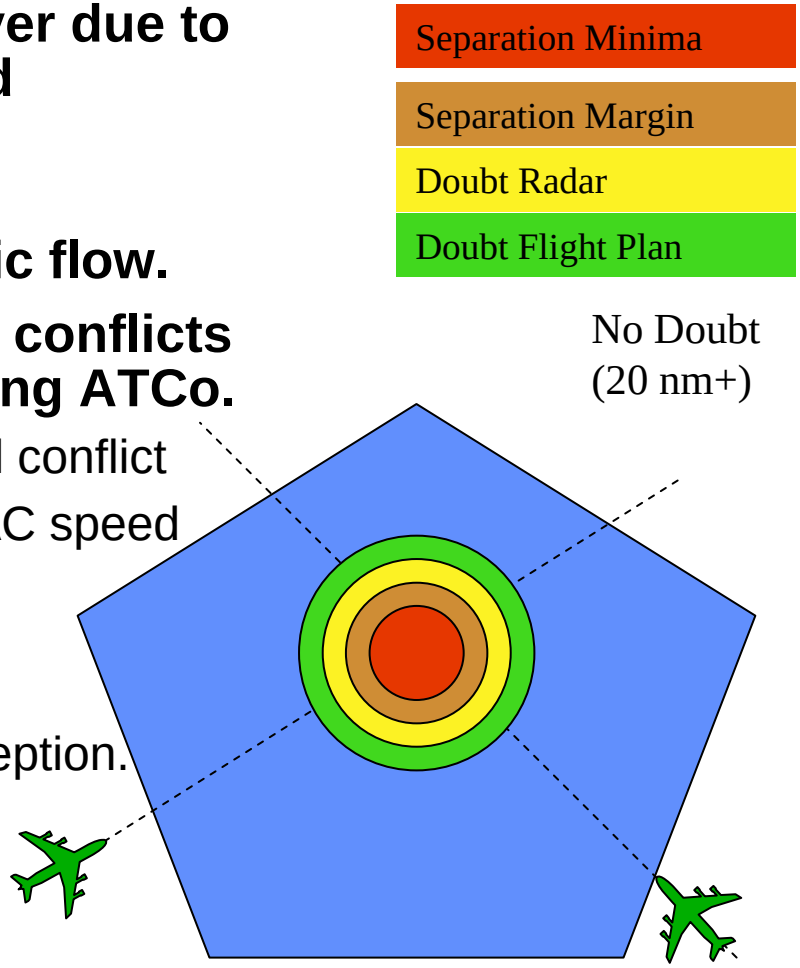
Subliminal control: ground automation “removes” potential conflict by minor alterations of aircraft speed or rate of climb/descent.

- **ATCo add large margins of maneuver due to limited accuracy of AC position and trajectory available to them.**
- **Uncertain ATM environment allows automated system to optimize traffic flow.**
- **Ground automation removes traffic conflicts by acting on traffic without disturbing ATCo.**
  - 15-20 minutes in advance of a potential conflict
  - Solve conflicts by minor alterations in AC speed or rate of climb/descent
  - Variation in speed: - 12 % to + 6% of current speed.
  - Speed modification outside ATCo perception.



Risk Assessment Model

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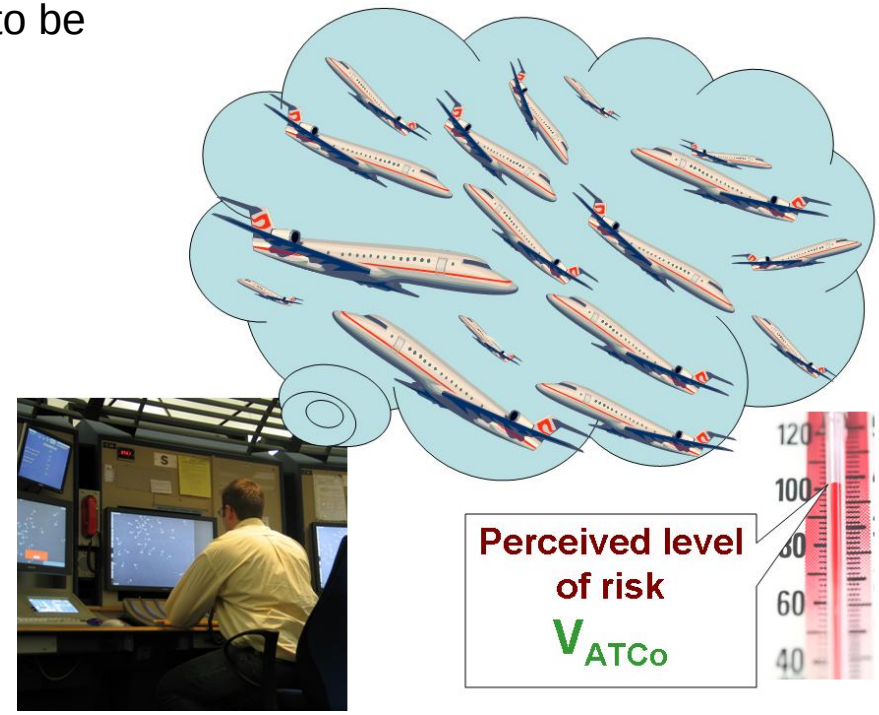
- **ATCo act on traffic whenever they feel a risk of loss of separation.**
- **Conflict Detection**
  - Estimate level of risk perceived by ATCo
- **Conflict Resolution**
  - Clearances to AC create traffic that minimizes risk perceived by ATCo.

- **The perceived level of risk is a function of several parameters**
  - number of potential conflicts which need to be monitored
  - geometry of these conflicts
  - time before the situation becomes critical
  - complexity of the trajectories (approach pattern, proximity of a turning point)

- **Early experimental results show**
  - speed changes up to 12% go unnoticed
  - large inter-individual differences
  - variation of relative speeds between neighboring aircraft more significant than absolute speed variation of 1 AC



4D Trajectory Management

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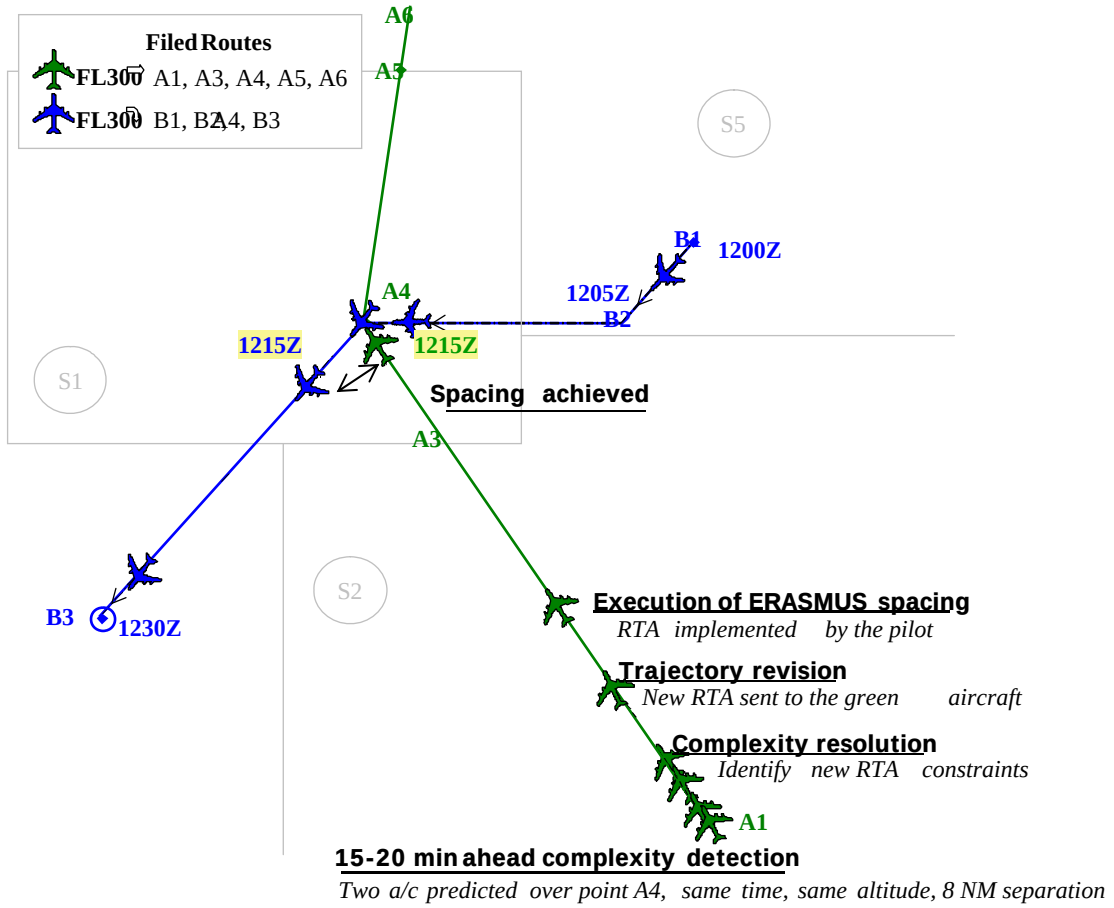
- **ERASMUS Conflict Resolution relies on 4D Trajectory Management**

- Allows airborne guidance systems to fly AC in most cost-effective manner
- Speed changes translated into AC crossing time at specified fix.
  - A: Arrive at fix At/After 1215 Zulu
  - B: Arrive at fix At/Before 1212 Zulu
- Ground automation system assigns different crossing times to different aircraft
- Crossing times uplinked to aircraft FMS's
- AC uses Trajectory Prediction function to evaluate feasibility of new time constraint
- If accepted, AC uses RTA guidance function to comply with assigned crossing time.



Trajectory Prediction Accuracy

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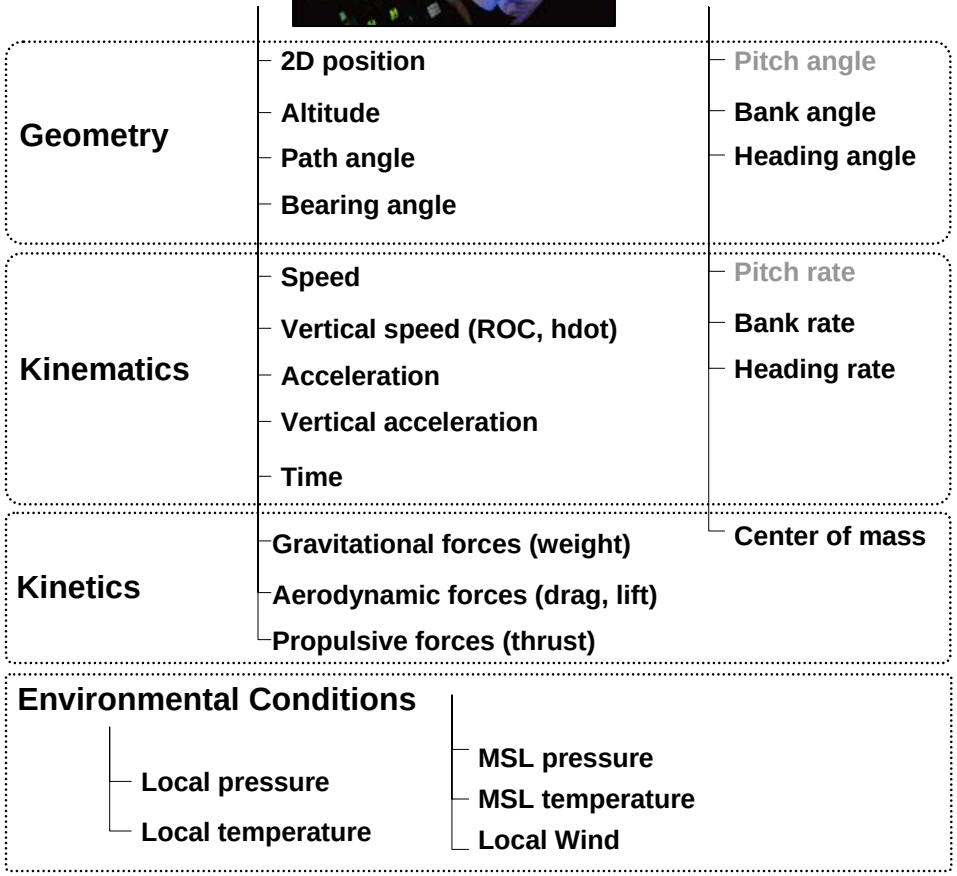

- **Reduce separation margins used in CD&R**
- **Generate more accurate 4D trajectory preds**
  - **Air / ground data exchange of**
    - AC state data
    - weather data
    - Aircraft / Pilot intent
- **Trajectory prediction accuracy depends on how accurately**
  - **disturbances (primarily wind) are represented,**
  - **aircraft performance can be modeled,**
  - **aircraft can be controlled to the planned trajectory.**
- **Airborne Flight Management Systems (FMS)**
  - **precise values of aircraft parameters (e.g.,**
    - local sensed weather
    - aircraft/pilot intent
    - aircraft state data
    - 4D trajectory predictions data.
- **Ground System**
  - trajectories of all AC involved in potential conflicts
  - ATCo intent
  - up-to-date weather forecasts and measurements
- **Datalink enables automated data exchange, contract negotiation.**

Reference:
"The COURAGE Framework: The Big Picture *Understanding Trajectory Prediction Technology," by* Francisco A Navarro, Boeing Research & Technology Europe – June 22nd, 2006

Architecture of Subliminal Control System

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a) ADS-B broadcast of AC trajectory & environmental conditions

d) ATC ground system uplinks RTA clearance to AC via CPDLC.
Flight crew verifies if RTA constraint is feasible; accepts or rejects clearance.

e Meteo Forecast

a Predicted air Trajectory

d RTA requests & responses

Data Link Solution(s)

ATC Ground system

c RTA requests & responses

ATC Ground system

b

Subliminal Control Application

b

Meteo Forecast & Local meteo data

Current position information
Raw predicted air trajectory
Air/ground consolidated trajectory prediction

e Meteo data

Airline Operations

Meteo Forecast

Meteo Office

b) Subliminal Control application collects information from all European ATC ground systems -- gains a complete knowledge of the traffic.

e) Meteorological information is disseminated to the Subliminal Control application and to AC to improve accuracy of both air and ground TP's

Technology Readiness

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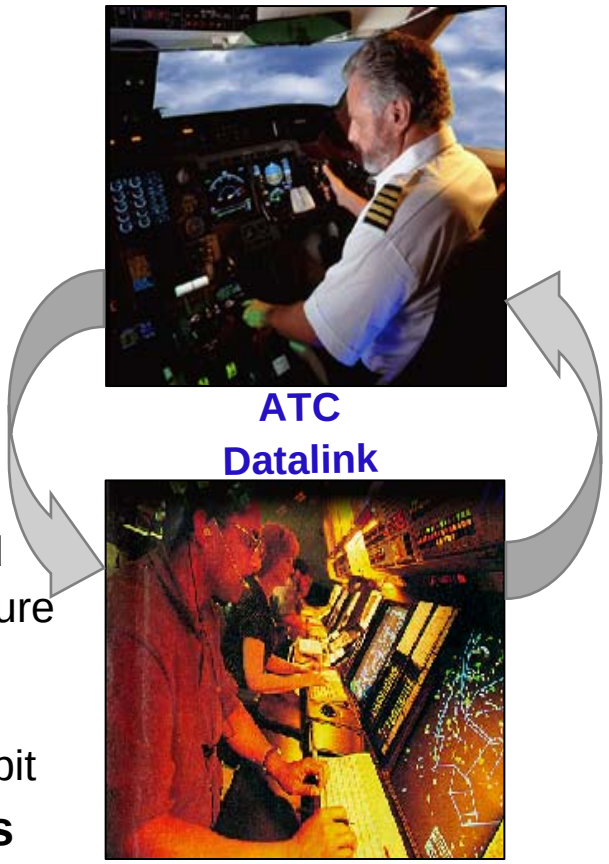
- **Automatic Dependent Surveillance – Broadcast (ADS-B)**
  - Aircraft automatically transmit accurate navigation measurements to ground & aircraft
  - Can include near-term trajectory intent and additional data
- **Controller Pilot Data Link Communication (CPDLC)**
  - Enables exchange of clearances between ATCo and pilots.
- **Deployment in Europe**
  - ADS-B in Europe will use 1090Mhz Extended Squitter
  - CPDLC in Europe will use VHF Digital Link (VDL) Mode 2
  - Local implementations of ADS-B using VDL Mode 4
- **Mandated in Europe by 2015**
  - At least 75% of flights and core Europe centers DL equipped
  - Aeronautical Telecommunications Network (ATN) infrastructure deployed
- **FIS-B: Flight Information Service – Broadcast**
  - Uplink of accurate weather and airspace information to cockpit
- **Required Time-of-Arrival and 4-D trajectory contracts**
  - Most modern FMS capable of RTA guidance in cruise



Potential Benefits

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- **Improved Air Ground Cooperation**
- **Data exchange (via ADS-B, CPDLC & FIS-B)**
  - Increased accuracy of both ground and airborne trajectory prediction systems
  - Reduced uncertainty in future AC positions
- **Greater trajectory prediction range and accuracy**
  - Earlier solutions of potential problems
  - Enhanced overall traffic efficiency and predictability.
  - Contributes to an increase in safety.
  - Improved A/C separation minimums
- **Progressive automation enabled by subliminal control concept**
  - Reduced voice communication channel congestion.
  - Reduced controller & pilot workload
  - Increased enroute airspace capacity
  - Maintained ATM safety levels
  - Better repartition of work between ATCo and computer systems.
- **RTA Guidance and trajectory control**
  - RTA guidance is more fuel-efficient
  - Reduction of environment noise and emission.

Conclusion

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- **Significant improvement in ATM services have long been predicted from the use of 4D information provided by airlines or aircraft FMS.**

- **Expected benefits of RTA-based Air Traffic Flow and Capacity Management**
  - greater predictability
  - improved safety
  - reduced holding and vectoring
  - improved arrival management
  - efficient aircraft operation and fleet management.

- **Subliminal control is an illustration of these improvements.**

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